

“A Chemical Study of the Phosphoric Acid and Potash Contents of the Wheat Soils of Broadbalk Field, Rothamsted.” By BERNARD DYER, D.Sc., F.I.C. Communicated by Sir J. HENRY GILBERT, F.R.S. Received November 9,—Read November 15, 1900.

(Abstract.)

In the ‘Journal of the Chemical Society’ for 1894 (vol. 65, ‘Transactions’), there appeared a paper by the author, “On the Analytical Determination of probably available ‘Mineral’ Plant Food in Soils,” in which the use of a 1 per cent. solution of citric acid was proposed as a means of approximate differentiation between the total and probably available phosphoric acid and potash, the method proposed being the result of an attempt to imitate, in the solvent, the acidity of root-sap, based on a preliminary examination of the acidity of 100 specimens of flowering plants of some twenty natural orders. To test the method, it was then applied to samples of the soils of the various barley plots in Hoos Field, Rothamsted, kindly placed at the author’s disposal by the late Sir John Lawes and Sir Henry Gilbert. The method, having yielded results fairly consistent with the greatly varying mineral history and known fertility of these various soils, has now been applied by the author to the investigation of the soils of a number of the Wheat plots of Broadbalk Field, also kindly placed at his disposal by Sir John Lawes and Sir Henry Gilbert on behalf of the Lawes Agricultural Trust Committee. Twelve representative plots were selected, and the samples examined include not only the surface soils to a depth of 9 inches, but also, for each plot, the second and third consecutive 9 inches of subsoil. The samples were drawn on the completion of the fiftieth season of continuous wheat growing, but earlier sets of samples, of both soils and subsoils, taken in 1865 and 1881, were also simultaneously examined.

The present paper gives an account of this work. It includes a summarised history of the manurial treatment and crop yields of each plot at the different periods, and gives, for each sample of soil and subsoil—fifty-one in all—the results of determinations of total phosphoric acid and of potash soluble in hydrochloric acid; and also of phosphoric acid and potash soluble in a 1 per cent. solution of citric acid.

The differences between the total percentages of phosphoric acid in different soils, unmanured and variously manured, correspond fairly well with their history; but in the absence of a knowledge of such history, these differences would not suffice to give any indication of the profound differences known to exist in the phosphatic condition and fertility of the soils. The relative proportions of citric acid

soluble phosphoric acid, however, appear to afford a striking index to the relative phosphatic fertility of the soils. In the subsoils, the irregularities and variations in the natural and original phosphoric acid of the subsoils themselves are such that the total percentage tells us nothing; while the citric acid results frequently show striking and consistent differences, and are also of considerable interest when studied in connection with the problems of root-range and subsoil-feeding, which are discussed in examining the results of the individual plots. In the surface soils, the average ratio of phosphoric acid, on the plots manured with superphosphate and ammonium salts, with and without various additions of alkaline salts, to that in plots not manured with phosphates for fifty years, was 1·65 : 1, while the citric acid soluble phosphoric acid ratio for the same groups was 5·46 : 1. On the two dunged plots the ratio of total phosphoric acid to that of the plots not phosphatically manured is 1·78 : 1 and 1·36 : 1 respectively; while the corresponding ratios for citric acid soluble phosphoric acid are 6·83 : 1 and 3·91 : 1.

The probable limit denoting phosphatic deficiency for cereals seems to be, as deduced from this investigation, between 0·01 per cent. and 0·03 per cent. of citric acid soluble phosphoric acid in the surface soil. That is to say, a percentage as low as 0·01 seems to denote an imperative necessity for phosphatic manure, while as much as 0·03 would seem to indicate that there is no such immediate necessity. For root-crops —more especially turnips—the limit would probably be higher.

The results, generally, show that by far the greater proportion of unconsumed manurial phosphoric acid, though originally water-soluble, is accumulated in the surface or first 9 inches, but that in the case of dung there is considerable descent into the second and third 9 inches, and that, in the case of superphosphate accompanied by constant dressings of potassium, sodium and magnesium salts without nitrogen (full supply and small utilisation), there is evidence of a tangible descent into the second and even the third 9 inches. In the case of the chemically manured plots, not only is the greater part of the calculated accumulation found by analysis in the surface soil, but a large proportion of it is found in a condition in which it dissolves in a weak solution of citric acid. This reagent also enables us to trace qualitatively the descent alluded to in the subsoils. Potassium, sodium, and magnesium salts have a distinct influence in the retention of the phosphoric acid in a less fixed and presumably more available condition, the effect increasing as the saline applications are greater.

The superabundance of phosphoric acid estimated to have been supplied in dung for fifty years is less satisfactorily accounted for than is that on the chemically manured plots; and even allowing for the difficulty of accurately estimating the phosphoric acid in the dung, it seems probable that there has been a considerably greater descent

from the surface soil into the subsoil than on the chemically manured plots, probably accompanied by fixation of some portion in an unavailable state.

Strong hydrochloric acid, as a solvent for potash in soil analysis, is shown to be practically useless as a gauge of potash fertility where there is an abundance of total potash in mineral combination, as silicates, &c. No concordant results are obtainable except by working under the strictest arbitrary conditions, and the results, even when concordant, have little meaning apart from an independent knowledge of the history of the soil. With this knowledge the results are interesting, but in its absence are of little use except in extreme cases.

The results obtained by citric acid, however, are strikingly instructive and consistent. To illustrate this, it may be stated that the ratio of the average quantity of hydrochloric acid soluble potash in the surface soil of three potash-dressed plots to the average quantity found in seven plots not dressed with potash was 1.20 : 1. The citric acid soluble potash ratio, however, was 6.75 : 1. The plots dressed with dung for fifty years and nine years respectively gave, as compared with the same seven non-potash plots, hydrochloric acid soluble potash ratios of 1.27 : 1 and 1.23 : 1, while the citric acid soluble potash ratios were 10.67 : 1 and 9.17 : 1.

Probably when a soil in the surface depth contains as much as 0.01 per cent. of citric acid soluble potash, the special application of potassium salts is not needed.

The largest accumulation of unused manurial potash, whether applied as dung or as potassium salts, is in the surface soil ; but a large proportion is also found by citric acid in the second and even in the third 9 inches. The subsoil accumulation is most evident in the dunged plots, and on the plot which, in addition to potassium salts, has received superphosphate with sodium and magnesium sulphates, but without nitrogen (abundant supply and small utilisation). Both sodium and magnesium salts, in presence of phosphates and nitrogen, have exercised a distinct influence in increasing the proportion of citric acid soluble potash in all depths on the plots on which no potash has been applied for fifty years, and which still maintain a higher yield of potash in their crops than that given by the plot with superphosphate and ammonium salts alone, though the equivalent of the potash added originally has been practically exhausted. Furthermore, sodium and magnesium salts, used in conjunction with potassium salts, have caused a larger retention of potash in a citric acid soluble condition than when potash has been applied without them, although the potash yielded in the crops has been greater under the influence of the other alkalies alluded to.

It is usually supposed that potash is pretty fairly retained by the surface soil of land containing, like the Rothamsted land, a fair pro-

portion of clay. That this is the case, as compared with sodium salts, is beyond doubt (see paper by the late Dr. A. Voelcker, "On the Composition of the Waters of Land Drainage," 'Journal of the Royal Agricultural Society of England,' 1874); but the series of analyses of the Broadbalk subsoils that has now been made by means of weak citric acid solution, shows that potash, though "fixed" relatively to soda, is far more migratory than phosphoric acid, and descends much lower into the subsoil. At the same time it appears probable that a portion of it passes into a fixed and stable form of combination, from which weak citric acid fails to dislodge it.

The results yielded by the samples of soil and subsoil taken from the same plots at the different periods afford instructive comparisons, notwithstanding the age of the earlier samples at the time of their examination, which might have been expected to be responsible for considerable modifications in the condition of the less stable chemical compounds contained in them.

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In consequence of the death of Her Most Gracious Majesty Queen Victoria, which took place on the 22nd of January, the meetings of the Society were suspended, by order of the President, until after the funeral of Her late Majesty, which took place on the 2nd February.

*February 7, 1901.*

Sir WILLIAM HUGGINS, K.C.B., D.C.L., President, in the Chair.

The President, in moving that a dutiful Address of Condolence and Homage be drawn up and presented by the Council of the Society to His Most Gracious Majesty the King, said:—

"The crape upon our Mace would remind us, if indeed we needed to be reminded, of the sorrow which is uppermost in every heart. We mourn to-day the greatest Queen the world has known—truly great by the supreme example She set, in Her own person, of sustained nobility of purpose, and of devotion to duty, and by the influence of Her wise and understanding heart, for the world's good, upon the councils of the Empire. We mourn more than a great Queen—a gracious Lady who by the brightness of Her domestic virtues, and Her rare power of kindly sympathy with Her subjects in all their joys and sorrows, had in a real sense become the Mother of Her Peoples. As Fellows of this Society, we mourn further a Sovereign Patron, who by Her enlightened encouragement and protection, has made possible through the sixty-